

age basin to have been remarkably accurate and reliable. After the middle of May, the time interval between the rating stations at Elgin and Fruita and the gauge at Yuma is about 12 days. By estimating the discharge at the upper stations a couple of days in advance, a general prediction for the extreme lower division of the Colorado can be made two weeks before the occurrence of the crest stage at Yuma. The final check at Topock is made six days in advance of the arrival of the flood crest at Yuma.

FLOOD OF OCTOBER 22-25, 1923, IN CANAL ZONE.¹

By R. Z. KIRKPATRICK, Chief Hydrographer.

[Balboa Heights, Canal Zone, Nov. 23, 1923.]

The week previous to the flood, Isthmian weather conditions were influenced by a West Indian hurricane, reported as central between Colon and the Island of Jamaica. Strong south and southeast winds were experienced and unusually dry weather for this season of the year occurred. Whether or not the hurricane had any influence on the extreme rainy period that followed is conjectural; however, as soon as the center of the disturbance had moved northward sufficiently that it no longer caused prevailing southerly winds, normal direction of northerly and westerly winds was again recorded; their velocity increased and conditions of the "norther" type began.

Rainfall.—Early Sunday morning, October 21, rain began to fall and continued with few breaks until Saturday, October 27. The temporary lull in the storm that occurred on the 23d was a very fortunate occurrence, in that it gave a few hours for lowering the already high level of the lake and thus facilitated the handling of the enormous quantity of water that came in on the 24th. Previous rainfall records were broken and new maxima established at several stations north of the Continental Divide. The following table gives the amount of rainfall recorded at selected stations during the storm period:

Rainfall (inches).

Date.	Porto Bello.	Colon.	Gatun.	Monte Lirio.	Gambos.	Alhajuela.	Vigia.	Pedro Miguel.	Balboa Heights.
Oct. 21....	1.48	4.26	4.58	4.94	1.88	0.89	0.34	0.57	0.36
Oct. 22....	3.27	9.02	9.09	6.84	6.75	7.33	7.40	3.64	3.14
Oct. 23....	5.43	4.23	3.36	5.02	1.89	2.81	3.54	1.09	.88
Oct. 24....	4.17	10.03	10.99	7.97	4.64	8.22	7.51	3.65	2.98
Oct. 25....	1.96	1.76	.63	1.58	.35	.34	.38	.09	.04
Oct. 26....	3.78	5.94	3.98	4.58	.90	.16	.57	.10	.01
Oct. 27....	1.56	.71	2.54	4.04	2.06	1.75	2.17	.69	.35
Total..	21.65	35.95	35.17	34.97	18.47	21.50	21.91	9.83	7.76

A maximum 24-hour rainfall of 12.25 inches was recorded at Gatun from 7:34 p. m. on the 23d to 7:34 p. m. on the 24th. This breaks all records for 24-hour isthmian rainfall, the previous maximum being 10.86 inches at Porto Bello on December 28-29, 1909.

In order to give a comparison of the recent flood with that of December, 1909, the following table showing rainfall for this period is furnished below:

Rainfall (inches).

Date.	Porto Bello.	Colon.	Gatun.	Monte Lirio.	Gambos.	Alhajuela.	Vigia.	Pedro Miguel.	Balboa Heights. ¹
1909.									
Dec. 26....	5.55	3.69	3.99	5.35	2.66	5.56	2.25	2.12	2.16
Dec. 27....	2.21	1.85	3.84	1.00	1.10	1.70	(²)	2.31	1.31
Dec. 28....	3.64	.50	.21	.62	.32	3.49	.....	.06	.06
Dec. 29....	7.96	.36	.30	.10	.34	1.09	.....	.06	.20
Dec. 30....	1.94	3.29	2.36	2.77	2.18	2.91	.....	2.25	1.16
Dec. 31....	1.07	.40	.84	.18	.08	.02	.....	.05	.08
1910.									
Jan. 1....	3.02	1.13	.97	.78	.30	.24	.....	.36	.03
Total....	28.39	11.22	12.51	10.83	6.98	15.01	.....	7.21	5.00

¹ Station then Ancon.

² Station washed out at 8 a. m., 26th.

A comparison of the two tables shows that while the rainfall at the headwaters of the Chagres and Pequeni Rivers was lower during the recent flood, the rainfall over the Gatun Lake area, especially the northern end, was about three times as heavy as during the 1909 flood period.

THE CHAGRES RIVER.

Alhajuela.—A slight rise on the Chagres occurred in the early morning of the 21st, but the crest was soon reached and the river dropped to elevation 93 feet and continued near this elevation until the beginning of the big flood. At 9 a. m. on the 22d, the river began to rise rapidly, continuing to rise steadily until 10:30 p. m., when a crest of 117.40 feet was recorded. The crest of the flood really lasted from about 9 p. m. until 12:30 a. m., after which it fell about as fast as it had risen, reaching 99.20 feet at 6:30 p. m. of the 23d. A second and slower rise then began, reaching elevation 112.80 feet at 4:30 p. m. of the 24th. This second crest was of shorter duration, lasting from 4 to 5 p. m., after which the river dropped about as rapidly as it had risen, and was at elevation 101 feet by 7 a. m. the morning of the 25th. From this point the drop in the river was very slow.

Vigia.—At Vigia the initial height of the river was 128.40 feet at 8 a. m. of the 22d. The rise in the river began about 45 minutes earlier than at Alhajuela. No record was obtained after 6:45 p. m., owing to the instrument house being flooded. Telephone communications between Alhajuela and Vigia were also severed about this time and nothing further was heard from Vigia

¹ See MO. WEATHER REV., Oct., 1923, 51:530.

until several days later. All the rods with the exception of the upper one, were either washed away or overturned. The observer at Vigia, however, obtained a crest height of 167.80 feet on the upper rod around 10 p. m. of the 22d.

Calle Larga.—An actual gauging made with current meter between 8:05 and 8:30 p. m. of the 22d with the river at elevation 129.20 feet (116.65 feet at Alhajuela) showed a maximum surface velocity in midchannel of 11 miles an hour and a discharge of 101,190 cubic feet per second. Judging from this gauging the river at its maximum height of 117.40 at Alhajuela was probably discharging 108,800 cubic feet per second.

Limon Plantation.—On the peninsula formed by the junction of Chagres and Gatuncillo Rivers the flood reached a crest height of about 105 feet. This height was due partially to the Gatuncillo, which was in high flood. The Limon Commissary was swept away about 7 p. m. of the 22d. Below the mouth of the Gatuncillo the crest of the flood was not so high, the water stage register, located a short distance below, showing a crest height of 102.20 feet. Fifteen thousand banana trees were washed out at Limon Plantation and other damage done.

Juan Mina.—Juan Mina, in normal river stages a part of Gatun Lake, really became a part of the Chagres River during the flood. The water was 16 inches deep on the floor of the commissary. What part the Chilibre River had in causing the stage at Juan Mina is not known. It was probably discharging as much water in proportion to its size as the Gatuncillo.

Comparison with 1909 flood.—Calculations based on the gauging obtained at Calle Larga indicate that from 4 p. m., October 22d, to 8 a. m., October 23, approximately 5.121 billion cubic feet of water passed Alhajuela, and for both flood periods, 9 a. m. October 22, to 12 midnight, October 27, approximately 14.290 billion cubic feet or 66 per cent of the total October Chagres flow occurred. Applying our present discharge curve to Alhajuela gauge heights during the flood period of December 26, 1909, to January 1, 1910, we find that from 10 a. m., December 26, to 4 a. m., December 27, 7.282 billion cubic feet of water passed Alhajuela; and for the flood period from 7 a. m., December 26, 1909, to 12 midnight, January 1, 1910, approximately 20,000 billion cubic feet came down the Chagres. Roughly the October flood of 1923 was 70 per cent of the greatest flood on record, that is, as far as the Chagres River above Alhajuela is concerned.

GATUN LAKE.

Gamboa.—Like Juan Mina, Gamboa is at present a part of Gatun Lake, but during the extreme flood period—that is, while the Chagres was near its crest height—it became in some respects a part of the river, for a maximum velocity of 10 miles an hour was recorded here and canal traffic would have been impossible from 5:30 p. m. of October 22 to 10 a. m. the following morning. Dredging operations were suspended and a tug could not pass the bridge at 9 p. m. with the current running 7.4 miles per hour. Heavy driftwood passed the bridge during the evening of the 22d and the bridge boom was broken. Canal traffic continued during the minor flood of the 24th, but the S. S. *Agristone* went aground on the west bank near Gamboa shortly after noon. Traffic was suspended at about 6 p. m. in order

that the lock culverts could discharge water. A maximum elevation of 88.42 feet was recorded at 1 a. m. of the 22d and a secondary maximum of 88.25 feet was recorded at 5:30 p. m. of the 24th. Current measurements at Gamboa with a current meter were impossible, but the float method was used over a course of 175 feet. A report in detail of the currents at Gamboa Bridge has been made.

Pedro Miguel.—The lake height at Pedro Miguel followed closely the rise in the lake at Gamboa, Gaillard Cut being in many respects a backwater arm of the Chagres flow, but surges in the cut superinduced by Pedro Miguel lockages aggravated the already high elevation; shortly after midnight of the 22d–23d and again on the afternoon of the 24th water began to pour through the strut slot into the bull wheel pits at Pedro Miguel Locks. A maximum height of 88.85 feet was recorded here at 5:15 p. m. of the 24th. An elevation of 88.65 feet occurred at 12:20 a. m. of the 23d.

Monte Lirio.—The lake height at Monte Lirio was influenced locally by the discharge of the Gatun, Agua Sucia and Agua Clara Rivers, which must have been in high flood. A maximum height of 87.75 feet was recorded on the afternoon of the 24th and an elevation of 87.60 feet occurred during the morning of the 23d. No data regarding currents under the Monte Lirio bridge are available; ocular reports say they were considerable.

Gatun.—The lake began to rise at 8 a. m. of the 22d, with an initial height of 86.16 feet, and continued to rise steadily, irrespective of spillway and lock culvert discharge, until 7 a. m. of the 23d, when an elevation of 87.48 feet was reached. A temporary lull in the storm allowed the lake level to be reduced to an elevation of 86.78 feet by 3:30 a. m. of the 24th. Closing of the lock culverts and resumption of canal traffic on the morning of the 24th, with the incident reduction in discharge of 36,000 c. f. s., together with a continuation of the storm, caused the lake to rise again, until a maximum elevation of 87.58 feet was reached by 9 p. m. The main part of the storm having spent itself by this time, the lake began to fall (due to the heavy spillage) and continued to drop until it had reached an elevation of 85.86 feet by 9 p. m. of the 26th. From this time it was allowed to rise slowly and held around 86 feet. The rise in the lake during the flood period was equivalent to a storage of 6.5 billion cubic feet.

Gatun Spillway.—At 6:36 a. m., October 21, two spillway gates were opened to take care of the lake's inflow. By 8 a. m. of the 22d no appreciable increase in elevation had occurred, but soon after the lake began to rise steadily. The situation was reported and permission obtained to open more gates. Two more gates were opened at 1:45 p. m., another at 3:20 p. m., one at 4:22 p. m., one at 4:34 p. m., one at 5:28 p. m., one at 7:12 p. m., one at 11:26 p. m., making a total of 10 gates running during the latter part of the night of October 22–23. An eleventh gate was opened at 8:51 a. m., October 23. This gate, in connection with two others, was closed at 11:30 a. m. of the 23d, leaving eight running. The eight gates continued to discharge steadily, and at 10:57 a. m. of the 24th a ninth gate was opened and left running until 1:21 a. m. of the 25th. The major part of the storm being over, the eight gates were continued in operation to reduce the lake elevation and closing began on the evening of the 25th. By the 28th it was possible to close all of the gates. An enormous quantity of water was discharged by the spillway during the flood. A maximum momentary discharge of 155,430 c. f. s. occurred during the time 11 gates were

open and during the 24-hour period from 7:12 p. m., 22d, to 7:12 p. m., 23d, 11.03 billion cubic feet of water was discharged. During the flood period, from October 22 to October 27, inclusive, 42.4 billion cubic feet of water was wasted over the spillway. This represents one and one-third times as much water as that contained in the lake between elevation 80 and 87 feet.

Gatun and Pedro Miguel Lock culverts.—Gatun and Pedro Miguel Lock sidewall culverts ran from approximately 9 p. m. of the 22d to 3 p. m. of the 23d, from 11.30 p. m. of the 23d to 7.45 a. m. of the 24th, and from 6 p. m. of the 24th to 10.30 a. m. of the 25th, discharging approximately 36,000 c. f. s. and a total of 5.4 billion cubic feet during the flood period. This amount of water is equivalent to 1.2 feet in Gatun Lake.

The Mindi Dike.—A limiting controlling feature of spillway gate operation was the condition of the Mindi Dike, more than eight gates running being considered dangerous in so far as the dike was concerned. However, with 9 and 10 gates open it stood the strain and for over 2 hours held against the maximum discharge of 155,430 c. f. s. when 11 gates were running.

Telephone communications.—With the exception of the line from Alhajuela to Vigia, no break occurred in communications until about 1 p. m. of the 24th, when a landslide north of Pedro Miguel severed all telephone communications. Hardly a half hour passed before the electrical division had arranged for wireless communications and this scheme was adopted until by 6:30 p. m. a temporary line was run around the slide and communications were resumed through Gamboa. Reports were received from Gatun over the automatic line and relayed to Balboa from Gamboa. By 1 a. m. of the 25th the temporary line was replaced by permanent line, and by 4:30 a. m. direct communication with Gatun was again established.

Total yield during flood period.—The amount of water that came into Gatun Lake during the flood period can be determined only approximately, owing to the uneven surface of the lake. The following table shows these approximate figures that were obtained by using lake values at Gatun and known requirements and discharges:

Probable Gatun Lake total yield (midnight to midnight).

Date.	Billion cubic feet.	Cubic feet second.	Date.	Billion cubic feet.	Cubic feet second.
Oct. 22.....	10.035	116,200	Oct. 25.....	5.159	60,000
Oct. 23.....	10.238	118,500	Oct. 26.....	3.550	41,000
Oct. 24.....	15.016	173,800	Oct. 27.....	3.985	46,000
			Total.....	47.983	1 92,600

¹ Average.

This total represents $1\frac{1}{2}$ times as much water as that contained in the lake between elevation 80 and 87 feet. It is probable that during the maximum rainy periods a momentary inflow as high as 250,000 to 300,000 c. f. s. occurred.

From a comparison of rainfall records of the flood periods of 1909 and 1923, it will be seen that over Gatun Lake the rainfall was about three times as heavy in 1923 as in 1909. This would indicate that the inflow over this region was probably three times as great as in 1909. Using this fact as a basis for a comparison of the two floods, a rough estimate of 1909 is possible. Assuming 300,000 c. f. s. as the probable 1923 flood maximum momentary inflow and knowing that approximately 100,000 c. f. s. came from the Chagres, 200,000 c. f. s. then was the inflow over Gatun Lake area other than the Chagres. If this value was three times what it was in 1909, in 1909 then 67,000 c. f. s. was the probable maximum momentary yield of the lake area. In 1909 approximately 154,000 c. f. s. was the maximum momentary yield of the Chagres above Alhajuela. $154,000 + 67,000 = 221,000$ c. f. s. probable maximum momentary yield of the 1909 flood. In other words, the 1923 flood was to the 1909 flood as 300 is to 221, or roughly there was one-third more water momentarily that came into Gatun Lake during the 1923 flood than there would have been in 1909 had there been a Gatun Lake.

In using the above figures it must be remembered that at best they are only rough approximations and should be considered as such. Anyhow, it is sure that this was preeminently a Canal Zone flood as to origin. The 1909 one largely originated in the upper Chagres. It appears that a combination flood would require careful and prompt attention to protect canal structures.

IS THERE AN ANTITRADE WIND IN THE EQUATORIAL REGIONS?¹

By Rev. S. SARASOLA, S. J.

[Observatoire National, Bogota, Colombia, Oct. 20, 1923.]

General circulation of the atmosphere.—In the discussion of the general circulation of the atmosphere writers frequently classify the winds as trade and antitrade. In the Northern Hemisphere the former blow from the northeast in the strata nearest the surface of the earth. On the other hand it is said that in the high regions of the atmosphere the antitrade winds move in the opposite direction, from the southwest, to complete in this manner the circulation of the currents.

We do not intend to study here the influences that are attributed to the earth in the deflection of the trade winds, such as the effect of the motion of rotation, nor shall we investigate the causes of those currents; our purpose is to inquire whether the observations that we have from the equatorial and tropical regions prove the existence of an antitrade in the Northern Hemisphere as

has been written again and again since the meteorologis Dove advanced that theory almost a century ago.

What arguments lead the writers to verify the presence of that upper current or antitrade which blows, according to them, from the southwest? These can be summarized under two headings: 1. The direction of the smoke from some volcanoes and the ashes carried by that equatorial current; 2. The direction of the elevated currents of cirrus and cirro-stratus clouds which, as those writers affirm, must be from the southwest.

Since this observatory (*Observatorio Nacional de S. Bartolomé*, Bogota, Colombia) is situated at an elevation of 2,645 meters on the *cordillera* of the Andes and since there are available observations for almost a year in addition to those published by Rev. L. Gangoiti, S. J., director of the Observatory of the College of Belén,

¹ Translated from manuscript text in Spanish by W. W. Reed, Washington, D.C., October 30, 1923.